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STUDY OF THE FRACTAL PROPERTIES OF CERES

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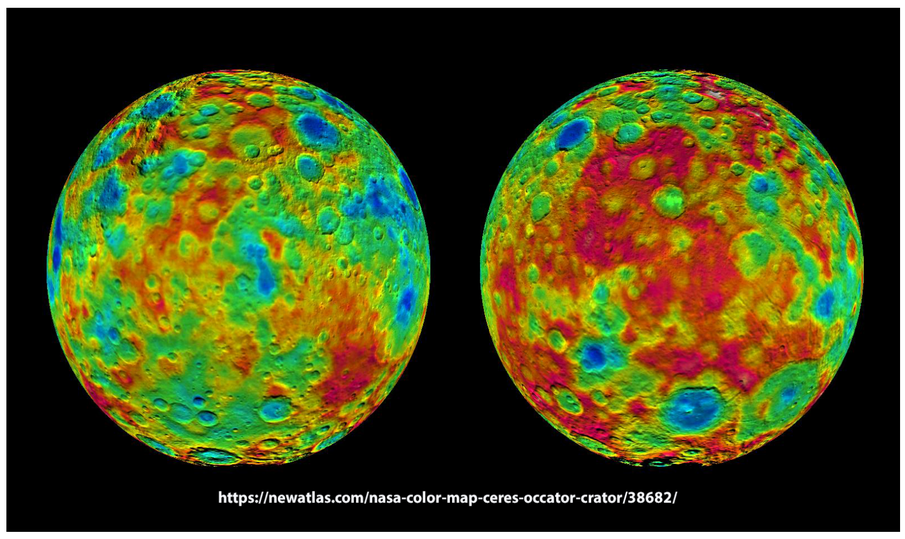

Introduction

Currently, Ceres is one of the most studied small celestial bodies. It is believed that the analysis of material composition of Ceres surface allows studying its internal structure and constructing a theory of Ceres's evolution. The "Dawn" spacecraft defined and matched an element base with the geological structure, which allowed comparing chemical parameters of the small planet with physical processes occurring there [1]. As a result, it was established that the composition of the dwarf planet represents a silicate body filled with water; in the course of evolution Ceres was heated and structurally modified, and geological process are still going on [2]. It should be noted, in order to create a complete picture of both the modern state and evolution of Ceres the knowledge of material composition must be integrated with the physical parameters of its surface [2]. In this work, fractal properties of Ceres asteroid were analyzed using the data from "Dawn" space mission.

Methods

The 3D model of Ceres constructed by us confirms the conclusion that the structure of Ceres surface (SCS) is a complex fractal system. The study of such objects requires the use of harmonic multi-parametric methods. When analyzing SCS, the Weierstrass-Mandelbrot fractal simulation method was used. According to this approach, models of complex fractal structures cannot represent a separate fractal and are described by multifractals – interrelated system of fractals [3]. These compound fractals are recursive, since they are invariant to the entire model of complex structure by both scale and symmetry [4]. Thus, multi-parametric fractal analysis allows representing systems similar to SCS as a fractal estimates spectrum. An advantage of fractal analysis is that local areas of the physical surface can also be investigated. In this work, the calculation algorithm by Minkowski was used. The surface model of Ceres asteroid was built by expanding altitude function into a regression harmonic series [5].

Results

The order of the expansion of altitude function depends on the number of reference points. The latter must exceed the planned accuracy of the model from 5 to 15 times. At the final stage, an overdetermined system for various local areas of topocentric information was solved with an aim of postulating the model accounting the external measures.

Using the harmonic expansion of altitude function into spherical functions the 3D model of Ceres was developed in order to carry out its fractal analysis. The fractal dimensions D for local areas and the whole model of SCS were determined. The variations of D ranging from 1.37 to 1.92 depending on Ceres's longitude and latitude were calculated. The main conclusion are as follows: 1) structure of Ceres surface varies more significantly in longitude; 2) in latitude the structure of Ceres is smoother; 3) the self-similarity coefficient varies in longitude rather quickly.

It should be noted that the produced fractal dimensions are considerably scattered in both longitude and latitude of Ceres. This fact confirms the presence of complex structure in the spatial model of the small planet. This also applies to the real physical surface of Ceres.

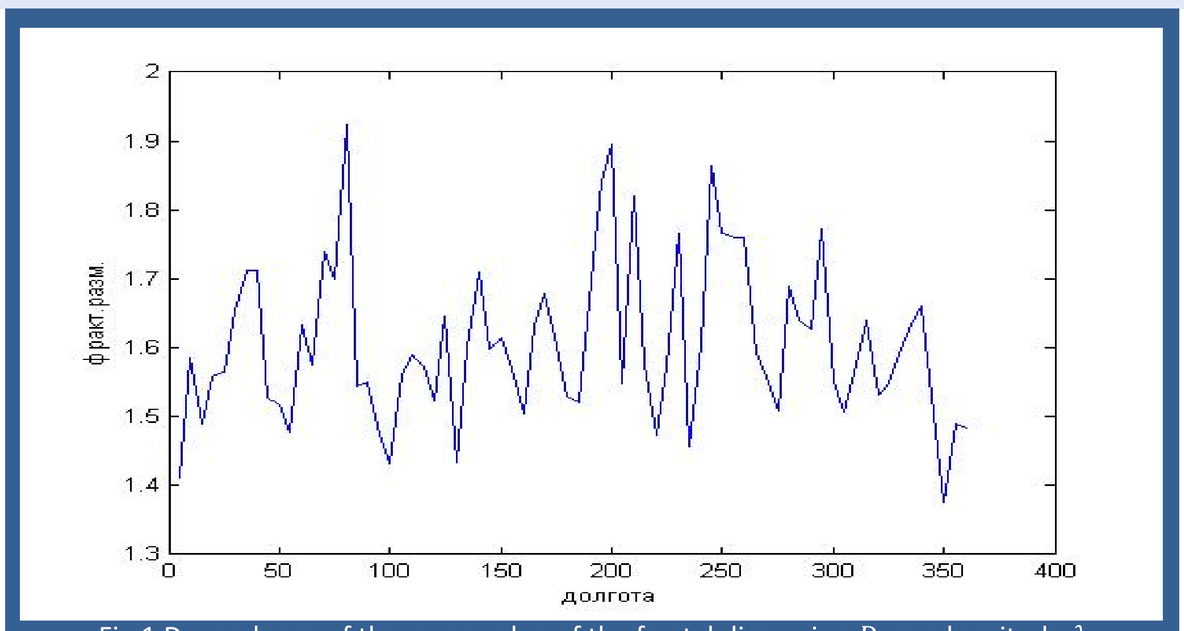

Fig.1 Dependence of the mean value of the fractal dimension $D_r$on longitude λ

Conclusion

Analyzing structure and evolution of celestial bodies includes various methods of statistical multiparametric analysis [6]. This also refers to planetary systems [7]. At the present time one of the promising directions of studying heterogeneous natural objects' structure is fractal geometry. For instance, the fractal analysis of the Solar system bodies' parameters has been conducted in the works [8]. The fundamental property of fractal objects is similarity or scaling when zooming. Investigations of fractal dimensions allow studying not only the structure, but the connection between structure and its formation processes as well [9]. The results of the work allow concluding that fractal simulation may provide independent values of fractal dimension for both the whole model of Ceres asteroid and its local macrostructural areas. The further development of the presented method of comparative fractal analysis will permit astronomers to investigate more local chemical and physical parameters and anomalies of SCS.

Acknowledgements

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